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ABSTRACT

In an effort to identify an idealized information technology (IT) system for education and training that could be implemented within a 10- to 15-year period, this paper looks at likely hardware configurations in the home, workplace, and educational institutions; identifies teachers' needs for IT systems that are not currently being met at a price suitable for education and training purposes; and specifies training functions that an idealized system might meet. Those functions that might be best left to teachers are examined, as well as those that might best be accommodated within an IT system. The paper concludes by suggesting two rather different types of idealized systems. In the first, a hierarchical model, teaching materials are centrally designed and produced, and all teaching functions are accommodated within the system. In the second, a networking model, IT is used primarily for facilitating communications between teachers and learners, and the teachers and learners create their own materials. It is noted that, in the end, what might appear to be a technical decision about requirements will ultimately depend on political priorities. (Author/DJR)

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DESCRIPTION OF IDEALISED INFORMATION TECHNOLOGY SYSTEM FOR EDUCATION AND TRAINING

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ABSTRACT

This paper attempts to identify an idealised information technology system for education and training inplementable within a 10-15 year period.

It looks at likely hardware configurations in the home, workplace and educational institutions, identifies teachers' needs for IT systems that are not currently being met at a price suitable for education and training purposes, then specifies teaching functions that an idealised system might meet.

The paper examines those functions which might be best left to teachers, and those that might best be accommodated within an IT system.

The paper concludes by suggesting two rather different types if idealised system: a hierarchical model, where teaching materials are centrally designed and produced, and where all teaching functions are accommodated within the system; and a networking model, where IT is used primarily for facilitating communications between teachers and learners, and where teachers and learners create their own materials.

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INTRODUCTION

Drawing up Utopias is usually a futile exercise, if treated as an end in itself. The future rarely works out the way even the wisest men predict. However, the exercise can be useful if used as a means of identifying key issues which need to be addressed in order to lead to a better system.

As well then as examining some of the advantages that information technology could bring to education and training if the right developments are encouraged, this paper looks at some of the conditions that will need to be met.

This paper is aimed at a time-scale of 10-15 years from now. This allows consideration of technology about which something is already known. Existing information technology will become more powerful, flexible, economical and pervasive over that 15 year period, but its fundamental nature is already fairly well understood, if not fully appreciated. Even if a major new breakthrough in information technology was to occur within the next year or so, it would in any case take 10-15 years to perculate through to the education and training sector, because of the time needed for understanding and adaptation amongst those who would use the technology.

AIMS FOR INFORMATION TECHNOLOGY IN EDUCATION AND TRAINING

What ideal systems of education and training can or should information technology deliver within 10-15 years?

There are two rather different but related aims that we should be striving for in Europe: one is concerned with the availability of education and training; the other with its quality.

The first aim is to widen the scope of education and training, so that it is available to anyone or any group that needs it. Richard Freeman, the Director of Britain's National Extension College, has argued that "open" learning should enable anyone anywhere at any time to study any subject to any level.

Thus if a works supervisor wants to improve his understanding of robotics while at home at two o'clock in the morning, he should be able to do so. If a major oil-company wishes to install on-site management courses for its managers all round the world at times that suit the managers, it should be able to do so. If an unemployed Welsh miner in a remote region wants to re-train as a sheep farmer, he should be able to do so. Information technology has the potential to make all these things possible, within reasonable cost.

The other major aim should be to improve the quality of education, by raising levels of education and training, and making it more satisfying and enjoyable to learners, without increasing costs. Again, information technology has the potential to do this.

However, for this potential to be achieved, certain conditions must be met.

This paper will try to indicate the kind of information technology systems and the conditions necessary to achieve this potential. This will enable clearer identification of areas and decisions which require priority in development over the next few years.

THE LOCATION OF LEARNING

There are three different kinds of location where most people undertake serious education and training: educational institutions, work and home.

While information technology is likely to shift the existing balance away from educational institutions to work and the home, the distinction is important, because of the nature of financing education and training in these three locations.

In Europe, study in educational institutions is primarily funded by the State; study at work tends to be funded mainly by employers; and study at home primarily by the individual.

LIKELY HARDWARE CONFIGURATIONS

The location of education and training is relevant for considering the level of investment in and the type of hardware that one can expect to find in each location, if normal market forces operate without national government or EEC intervention.

The Home

Over the next 10-15 years, there is likely to be steady growth in home access to individual "general purpose" technologies that could be used singly or in conjunction for educational purposes. Terrestrial broadcasting and printed newspapers are the main information technologies already available to almost all homes in nearly all EEC countries. The main growth areas appear to be telephones (over two-thirds of homes already, but likely to increase to 90% within 10-15 years), video-cassette machines (already approaching 50% of homes in some European countries), home micros (in around 35% of homes in some EEC countries), and compact discs. Towards the end of the 10-15 year time period, satellite TV and viewdata systems may also become widespread in homes in some EEC countries.

Less certain is the growth of video-discs and wideband cable TV in homes. Video-disc technology is not likely to take off domestically until there is a recordable system; even the most optimistic forecasts for wideband cable TV predict less than 50% home access by the turn of the century in any EEC country.

The most interesting and unpredictable development will be in the area of home micros. Power and range of function are both likely to increase within a price range acceptable for domestic purchase. Penetration into homes might also be encouraged by employers providing or subsidising home facilities for selected workers. However, variations in programming languages, functions and peripherals (modems, storage facilities, graphics, voice, etc.) will remain major problems for education, unless a major

European-wide initiative is successfully undertaken, or unless two or three major companies come to dominate the market. Also, there are some doubts as to whether "general purpose" micros (as distinct from computer games) will penetrate into homes of those on low incomes or without more advanced educational backgrounds.

Perhaps the most significant development though is the ability to link the home micro, via the public telephone system, to powerful mainframe computers. Not only does this allow access to more powerful operating procedures and large data-bases; it also opens up the possibility of easy and widespread communication via electronic mail.

The Workplace

The workplace is perhaps the most promising area of development for information technology in education and training. Companies can standardise internally on one system, are increasingly likely to have information technology systems already in use in any case for business reasons, and can where necessary invest in information technology for work-based training purposes, where benefits over traditional "off-work" training provision can be easily identified.

Educational institutions

Perhaps surprisingly, it will be in educational institutions (schools, colleges, universities) where the application of information technology to education and training is most likely to be problematic.

In both the home and the workplace, learning can be organised around information technology work stations for each individual learner. This will be much more difficult, for cost reasons, in the majority of educational institutions, unless a great deal more investment is made by the State in information technology for this sector.

Take primary schools for instance. There are just over 20 million children in primary schools in the EEC. Attendance is compulsory, and the teaching is almost universally done in large groups or classes of from 25 to 40 children or more. Recurrent yearly expenditure throughout the EEC on primary education is in the order of around 20,000 million ECUs. However, around 80% of this goes on teachers' salaries.

In British primary schools, there are just over 30,000 micros installed. Current provision means that there is one micro for every 160 primary school pupils in Britain.

This highlights a major difference between micros and television. Television in schools is used primarily in groups, sometimes with three or four classes watching together, then dividing up into their own classes for follow-up work. Micros though are best used with at most three or four pupils together at one time.

It is difficult to estimate how much hardware should be available in schools. However, the ideal situation would be where every pupil had the

means to access computing facilities at any time - in other words, a maximum of 20 million units for EEC primary schools. However, this would almost certainly be over-provision. While social and personal development remain major goals for primary education, there will be a great deal of time when the use of IT will be neither necessary nor appropriate.

On the other hand, the provision of about one hour per week "terminal time" per pupil would seem a very modest long-term goal for primary pupils. Nevertheless, given a maximum time of five hours a day for all kinds of instruction, this would still require one machine between every 25 pupils, or roughly one per class. This would mean a six-fold increase over current provision in Britain, and across the EEC as a whole an investment of 10,000 million ECUs in primary schools for hardware alone at current prices.

However, it is unlikely that schools in Europe will be able to make this level of investment. Currently, a British school needs to find just over 2,000 ECUs for what is considered now to be a minimum IT work-station requirement (a BBC Model B, disk drive, monitor and dot-matrix printer). With equipment expenditure in Britain averaging around 3,000 ECUs per primary school per year for **all** equipment, it will take many years for schools to equip themselves to a level where most pupils have access to a micro when needed, unless either the price of the hardware and peripherals drops rapidly, or there is massive additional funding from government.

It is worth noting that it has taken almost 20 years for most schools in Britain to equip themselves with television monitors and then video recording machines (without central government financing), to about the same extent as micros in schools today.

Much more hardware then is required, at a unit cost that is realistic for primary schools, given their other financial limitations.

One solution is to use networking or file serving within a school, where a more powerful central micro is linked to cheap terminals. However, this is still an expensive option, requiring hard-wiring, as well as the provision of sufficient numbers of screens, printers, and keyboards for individual use.

Another option is to use external network systems, such as, in Britain, Prestel Education or Times Educational Network, with cheap local terminals. Here hardware costs are only slightly reduced, and tend to be replaced by high telephone or subscription costs.

Another solution would be to centralise IT work stations in a school, in, for instance, the school library, ensuring intensive use by a variety of users. In this case, IT becomes just one resource of several available to the student. Again, though, the need to serve large numbers of pupils is likely to lead to lots of low-cost IT work-stations rather than to a few more powerful ones.

Equipment therefore lending itself more to group activities and time-sharing is likely to find most favour in schools; this suggests increased growth in video-cassettes, and towards the end of the five to ten year period stand-alone video-discs, plus networked, low-cost micro

systems.

In the more advanced level institutions, such as polytechnics and universities, one is likely to find more complex and powerful "stand-alone" systems existing in parallel with, and occasionally connected to, a centralised network of terminals linked to a powerful mainframe system.

Intervention or the free play of the market?

To what extent is deliberate intervention by the EEC or individual governments likely to influence the functionality of IT hardware for education and training in the next 10-15 years?

The use of information technology for education and training at **home** will depend very much on general market developments in information technology. There is little evidence to date of a large domestic market for equipment specially designed for educational purposes, nor evidence of the willingness of the public to spend substantially (i.e over £500 per annum) on home-based educational activities. Past experience suggests that education in this sector usually rides on the back of normal commercial developments.

Similarly, IT for education and training in the **work-place** in most instances will ride on the back of IT brought in for other commercial purposes.

It is only in the **schools** sector, where governments are going to have to find the money for hardware for schools, where a case might be made for developing hardware specific to educational purposes. This would still be a high risk activity, competing with "general purpose" developments which are often suitable in any case for education as well. Furthermore, it could only be justified if it could be shown that there are functions specific to education not being served currently by existing technology at a price that schools or their governments can afford.

Consequently, in order to define the ideal hardware configuration for education, it is necessary to define the main educational functions sought from hardware, and in particular, what functions are not yet available at the right price (which needs to be less than £250 a workstation for primary schools, to meet a minimum requirement of one hour a week terminal time per child).

TEACHERS' NEEDS

It is not though just a question of providing greater quantities of hardware, or even more powerful software. Not only must the quality of the system **as a whole** improve if it is to be used more widely by teachers, but the teachers' role with respect to information technology must also be considered.

It is essential to take into account the workload and training requirements of teachers. No matter how skilful a teacher may be in programming, nor how powerful an authoring system at the teacher's disposal, IT will not be

used if teachers have to spend a great deal of time preparing or adapting material to suit the needs of their learners. Until IT can be used as simply as a blackboard or duplicated worksheets, its use will be confined to dedicated "hackers".

What teachers need are systems which allow them to:

draw, colour in and add text

add their own (natural) voice to computer-based material

edit frames of computer or video material

easily combine computer material and computer control with full, moving video;

communicate easily with learners and other teachers, independent of time and place.

All these features can be provided by existing information technology, but at a price beyond the means of most teaching systems, and more importantly, such features at the moment demand a level of sophistication in IT skills which will prevent widespread use by teachers who see IT as a means to an end, not an end in itself.

Many doubt whether teachers will prepare their own material. However, unless teachers do, and in large numbers, there will be a great lack of suitable courseware. It is significant that in Britain, several publishers who started to produce and market computer courseware for schools are now pulling out of the market, because of the high cost and low take-up. It is also significant that in Britain, despite the major effort by MEP to develop computer literacy in teachers, only 6% of courses in humanities and geography use computers, and even in business and economics the figure is less than 20%. It is mainly in subjects where computing plays a key role as subject matter (maths and science) where computers are used by teachers.

The main teaching advantage of IT for schools is its potential for meeting individual needs, and the teacher is in the best position to assess what those needs are. Teachers therefore require a technology that is very simple to use, very flexible, and easily adaptable, with courseware which they feel they can control and adapt as necessary. The technology still has some way to go before it will meet the needs of a majority of teachers on these criteria.

There is also one other important characteristic of information technology which has major consequences for primary education. It encourages the development of individual or small group work which need not be confined to a classroom or even school. Many skills could be developed at home. Low-cost equipment suitable for both home and school use could prove to be extremely useful and popular, allowing easy transferability of study between work and home.

Much more emphasis is being given in the school system to generalisable

skills ("process" rather than "content"), and in particular learner autonomy, i.e. getting learners to accept personal responsibility for their own self-development. The emphasis increasingly in vocational education is then on **continuous** job-specific training, rather than once-off, initial training. This is necessary because of the rapid technological changes likely to occur in work, leisure and services, requiring people to adapt continually to changing circumstances.

An information technology system then that is going to be useful in this kind of climate must be one that can be very flexible and adaptable, so that new knowledge can be quickly incorporated, easily modified and mediated by teachers, one that can adapt to individual learner needs, and above all, one that is "transparent" to both teacher and learner.

That means that teachers do not have to become experts in programming, but can easily create or modify materials for themselves, can intervene and change things as necessary, and can incorporate new ideas and knowledge as it becomes available. For learners it means that they can concentrate on the learning tasks without concern about how to use the technology.

IDEAL EDUCATIONAL FUNCTIONS

What then are the features used by teachers to develop flexible learning?

Some of the features of good teaching are:

1. ability to diagnose learners' difficulties and choose appropriate alternative learning paths;

2. ability to present, store and make accessible large amounts of information using a wide range of symbolic representation (colour, movement, voice, text, graphics, etc.);

3. to structure information or knowledge in a manner appropriate to the needs of both teachers and learners;

4. to demonstrate correct procedures in appropriate sequences, in slow motion or from several angles if necessary;

5. to model or simulate complex phenomena so that learners can observe consequences of changing variables in a safe and controlled manner;

6. to provide feedback on learners' performance;

7. to provide suitable activities for learners, to enable them to develop mastery learning and skills of application

8. ability to provide unlimited practice and hence mastery of skills through repetition;

9. to enable learners to work at their own pace;

10. to provide education and training suitable to individual needs;

11. to adjust where possible to learner's previous knowledge and errors, and to adjust to learner's new knowledge and errors;

12. to allow for the accumulation of new knowledge, including that generated by learners.

It will be noticed that some of these functions are much better handled at the moment by teachers, while others can be handled better by information technology. At the same time, hardware already exists which can handle most of these functions. The limitations are lack of power on low-cost systems, lack of adequate computer software, and lack of adequate teaching materials (courseware) to exploit existing hardware and software. More powerful hardware at lower cost will help, but it is not the only development required.

TEACHER OR COMPUTER?

Information technology systems currently are not very good at functions 1, 3, 7, 10, 11, and 12. There are three reasons why these functions are proving difficult to emulate through computer technology:

lack of appropriate knowledge about how teachers make decisions in these areas;

the lack of appropriate programming languages needed to handle the volume of information and the decision-making processes required for these functions.

the enormous storage capacity required to handle the necessary knowledge for these decisions;

Better software is dependent on development in the first two areas, i.e. on progress in artificial intelligence, expert systems, and new programming languages. There remains the problem of very large storage capacities, which suggests the use of mainframe or at least minicomputers for some time to come, rather than low cost micros.

This prompts the following question: is it worth trying to build computer systems which emulate those areas which are already well served by human teachers? Would it not be better to concentrate on those areas which the teacher finds difficult, or to use technology to facilitate and spread those skills which are already well handled by human teachers?

It may well be possible, after many years research, to develop IT systems which can handle functions 1, 3, 7, 10, 11, and 12. But at what cost? What kind of equipment would schools and homes require? And how flexible will these systems be? Will they be easily amended by teachers, easily up-dated, and transparent to learners?

The danger is that by placing too much emphasis on artificial intelligence, control is taken away from both the teacher and, more importantly, the learner. The process of constructing materials via highly sophisticated systems based on artificial intelligence is likely to become so complex

that only a few specialists, isolated from the day-to-day educational process, can create learning materials.

In other words, is there a desire to replace teachers with machines? If there is not, machines must complement, not replace, the work of the teacher.

So where does this leave an ideal education and training system based on information technology?

HIERARCHIES OR NETWORKS?

Thus the choice of an idealised IT system for education and training requires a fundamental choice between a hierarchical or network approach.

The hierarchical approach

In the hierarchical approach, as much as possible is put into the machine system (which may integrate several discrete components, e.g. computer, video, telecommunications).

The machine system attempts to emulate as many features as possible of good teaching practice, with learners having to move away from the work station as little as possible for their instructional needs. All courseware is accessed through the work station; all activities are controlled and carried out through the terminal. The system provides remedial activities and final assessment.

To develop such a system, a great deal more research and development is necessary. A massive programme of research into artificial intelligence and expert systems applied to education and training will be necessary, as will access to powerful machines by both courseware producers and learners. Highly skilled teams of programmers and educational specialists will need to be set up to create teaching materials and software which will emulate good teaching practice; a continuous, on-going system of curriculum development, and adaptation and up-dating of courseware and software will be needed to take account of changing knowledge. This will require substantial changes in the organisation and management of the educational and training services.

The benefits of such an approach would be highly effective instruction in certain areas and a possible reduction in the teaching and training force, making savings on salaries; these savings would be essential to provide the finance for courseware development and hardware provision. Such approaches are likely to have particular relevance in industrial or commercial training, where knowledge and skills to be learned can be precisely identified, and do not change very rapidly.

The main dangers are likely to be lack of flexibility, slowness of change, centralisation and standardisation of teaching approaches, and the risk of ossifying teaching practice and some areas of knowledge. It would leave the design and presentation of teaching in the hands of a much smaller group of people than currently, with the danger that courseware production becomes isolated from the needs of learners. Underlying such an approach

is a real risk of dehumanising the teaching process.

The network approach

The emphasis in this approach is on information technology as a decentralised communication system between teachers and learners. The aim here is to use IT systems not to replace teachers, but to facilitate their communication with learners (and each other).

The IT work station would be but one component of the teaching system, with other components being books, television and face-to-face contact, with the various components not necessarily physically linked to one another.

Individual teachers would use information technology to help learners access information, to communicate with learners through electronic mail, and to create and amend their own teaching material; learners would also use the IT system for communication with their teacher, other subject experts and other learners.

What the machine system does not try to do is to emulate all the features of "good teaching", such as diagnosis, selection of appropriate remedial work, and management of the learning process. This is left to the teacher to do, based on personal knowledge of each individual learner's needs, strengths and weaknesses. Learners are also able to carry out learning activities outside the machine system, where suitable or convenient, e.g. in real situations, and to ask for help from a "live" teacher.

To develop such a system, there would need to be some development work on a relatively low-cost hardware system (micro-computer, monitor, disc-drive, printer, communications link with telephone system, audio and video-disc interface, and software packages for word-processing, electronic paintbrush, and simultaneous audio/data transmission); the aim is to enable teachers and students to create and access simply produced teaching materials, combining text, graphics and natural voice, and to transmit this material to each other electronically. Many, but not all, of these facilities are available already on low-cost micro-computer systems.

Also necessary would be a user-friendly electronic mail facility combined with an educational data-base, built up by the accumulaton of teaching materials created by teachers on their local work stations. This would require a powerful indexing system and data-management package, on a mainframe computer or a series of networked computers.

What is important is that the creation and accessing of the messages between teachers and learners should be technologically transparent, and that the hardware and courseware are accessible to educational users at low cost.

The benefits of this networking, modular approach is that it would enable teachers and learners to remain in control of the teaching process. It also allows for the rapid creation of large amounts of educational material specifically designed for individual needs. This material though can also be accumulated on a main data base, and accessed and amended by other teachers.

The importance of creating suitable courseware for information technology systems cannot be overstressed. The major obstacle at the moment to more widespread use of information technology in education and training is the lack of high quality courseware. This is partly because of the high cost of developing tutorial-style computer assisted learning, and costs will increase even more if artificial intelligence and expert system software is also to be incorporated.

Another advantage of a networked, modular communications approach is that if costs of hardware are kept down, it can open up the availability of information technology systems to a much wider range of users, including those in the home and the school. It is also very flexible, allowing for the latest expertise in subject matter to be accommodated, and a wide variety of approaches to teaching to be adopted. Lastly, it also allows learners to negotiate their learning with teachers, through the use of a genuine two-way system of communication.

The main dangers of such a system is that the quality of teaching does not necessarily improve, or that the teaching materials, while suitable for the purpose for which they were created, will not be suitable for other users, and that costs will increase. It is likely however to increase the flexibility of learning, particularly outside educational institutions, thus making education and training more accessible and more continuous for adults.

A compromise: the best of both worlds?

These are of course two extreme "Utopias". It would be possible to combine elements of both; for instance, a powerful, artificial intelligence based expert system could be added to the communications data base and accessed by individual institutions - at a price.

However, the two Utopias do reflect quite different approaches to the use of information technology in education and training. In a situation where priorities for research and development have to be set, it is important to identify the differences in requirements between these two approaches.

The emphasis in the hierarchical approach is on fundamental research into artificial intelligence, on the development of software and advanced programming languages, and a massive curriculum development.

The emphasis in the networking approach is on low-cost hardware developments (an extension of developments already implemented by European micro computer companies like Philips and Amstrad) and the development of educational communication systems, with some teacher training.

The needs for work-based training seem to be rather different from home-based or institutional-based systems. Hardware availability and cost is less of a problem for work-based organisations; what they need is powerful, high-quality courseware. For the other two sectors, what is required is more hardware, and the ability to create quickly and easily large quantities of material and make it available to large numbers of learners.

In the end, as always, what might appear to be a technical decision about requirements will ultimately depend on political priorities: which area of education and training should receive priority, and what educational approach in the use of information technology is considered most desirable?